Advanced Turbines — A FETC Perspective

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Good morning. It is a pleasure for me to be here today. I am surprised to see so many faces after the stock market crash. I thought everyone would be talking to their brokers. The good news recorded on TV this morning was that Bill Gates lost something like $1.75 billion. He may have to start charging for that Web browser. I thank Abbie and all the others who organized this conference — it's impressive how smoothly it is organized.

I would like to take some time this morning to talk about the achievements in the Advanced Turbine Systems Program and the DOE program in general, and then talk a little about the future of the RD&D program. I would also like to thank Sam Biondo for presenting about one third of my talk. First, let me answer the question I always get asked — and that is, how is the merger with FETC going, how is the combination of the two centers working out? From my own perspective, I think quite well. I work with people from both sites. I have staffs that work with me both at Morgantown and Pittsburgh as do all the other managers. We travel back and forth, and it is going pretty seamlessly at this point. I think the other good thing that has happened with the merger is that we are working better with Headquarters, and Headquarters people also participate on our product teams. Everything we do now is organized along product lines: product teams determine budgets and programs and Headquarters people participate on their end. FETC representatives also participate on Headquarters' teams, where we do strategic planning and help in the budget priorities. So from my perspective, the merger is going quite well.

The FETC mission is to ***solve national energy and environmental problems***. It is not just research — it's solving problems. Our budget for fiscal year 1997 is about $850 million, 40 percent of which is for the many clean coal projects that are in various phases of operation. We have about 700 RD&D demonstration projects in 49 states, which we conduct along with private-sector organizations, colleges and universities, non-profit research labs, national labs, and through international cooperation with other countries. In addition, we have a large number of in-house R&D projects. You'll have a chance to see some of those facilities if you take the tour at the end of the program tomorrow, and I think you will be impressed.

RD&D Program Areas

Our RD&D projects span four major areas:

- The first is Natural Gas Supply, Processing and Storage.

- Our second area is Environmental and Waste Management — technology for cleaning up the nuclear legacy of DOE's weapons production program.

- A most important program is our Advanced Clean Fuels Research, which is making strides in developing clean liquids from natural gas, coal, and other carbonaceous materials, including biomass, industrial residues and municipal solid wastes. These clean liquids can, early in the next decade, supply our transportation sector with premium-quality fuels.

- Another area that I would like to discuss in more detail today is Coal and Natural Gas Advanced Power Generation. In addition to Advanced Turbines, this program is fostering the development of Advanced Pulverized Coal Combustion systems such as the Low Emission Boiler System (LEBS) and Integrated Gasification Combined Cycle (IGCC) technology, both of which are on the brink of commercialization.

  IGCC can operate with natural gas or a coal-derived gas, pushing the efficiencies of coal plants — now at about 35 percent — to 60 percent (with "Vision 21"). Today, three IGCC plants are being demonstrated through the Clean Coal Technology Program in various locations throughout the country: Florida, Indiana, and Nevada.

I would like to take a few minutes to talk about the future of the coal and power systems program. Where are we going in the next several years? Will the successful industry/government partnership to develop advanced technology continue at its current level? What will happen to the budget? This is a critical time. We are facing the simultaneous convergence of several major policy issues or program drivers, any one of which could have major impact on the R&D program. These drivers can be broadly classed as either environmental or economic. I believe that there are five basic policy issues which are key drivers in the future directions of the RD&D program in fossil energy.

Driver 1: Global Climate Change

Sam Biondo covered the global climate change driver very well. I think this driver will have a major impact on our R&D program. On October 22, 1997, the President announced the instructions for the U.S. negotiators at Kyoto. He described a proposal that provides flexible market-based and cost-effective ways to achieve meaningful greenhouse gas reductions for the U.S. He noted that we cannot wait until the treaty is negotiated and ratified to act. The President's plan and the outcomes from Kyoto are likely to have significant impact on the Fossil Energy and the Energy Efficiency and Renewable Energy RD&D programs.

The comprehensive framework that President Clinton proposed includes **three elements:**

(1) A binding target of reducing emissions to 1990 levels between 2008 and 2012, including further reductions below 1990 levels in the 5-year period thereafter, and work toward further reductions in the years ahead.

(2) Flexible mechanisms for meeting these limits, such as a joint implementation system that allows a firm in one country to receive credit for investing in a project to reduce emissions in another country; and an international system of emissions trading.

(3) Both industrialized and developing countries must participate. The industrialized world must lead, but developing countries also must be engaged.

"The United States will not assume binding obligations unless key developing nations meaningfully participate in this effort."

The President proposed **a six-point plan** to provide incentives and lift road blocks to help find new and creative ways of reducing greenhouse gas emissions.

- Enacting tax cuts and making research and development investments worth up to **$5 billion over the next 5 years —** targeted incentives to encourage energy efficiency and the use of cleaner energy sources.
- Appropriate credit for early actions that companies take to reduce emissions.
- A market system for reducing emissions at the lowest possible cost in the U.S. or abroad; a system that will draw on the successful experience with SO_2 allowance trading.
- Reinventing how the federal government buys and uses energy. The federal government will be called on to play an important role in helping the U.S. meet its goal (e.g., 20,000 solar roof systems on federal buildings by 2010).
- Unleashing competition in the electricity industry — to remove outdated regulations in a way that will lead to even greater progress in cleaning our air and will deliver a significant down payment in reducing greenhouse gas emissions.
- Continuing to encourage key industry sectors to prepare their own greenhouse gas reduction plans. Work with state and local government to remove the barriers to efficient energy usage.

The President noted that the proposed plan will be phased in over time. It will start with a package of market incentives, tax cuts, and cooperative efforts with industry. Regular reviews will be performed to see what works best for the environment, the economy, and national security. Then, after accumulating a decade of experience, data, and technological innovation, the broad emissions-trading initiative will be launched to ensure that we hit our binding targets.

"It is important to remember that the U.S. Senate voted 95 to 0 that they wanted both developing and developed nations to be covered in any climate change treaty negotiated by the Administration."

What about the role of technology and R&D in solving this problem? In July of this year, President Clinton announced a new initiative — development of a Climate Change Technology Strategy (CCTS) — an initiative to seek low cost technical approaches to address climate change. He asked DOE to help plan this initiative. The Department's national laboratories and FETC prepared a report on the subject for delivery to the President in October 1997. The report is called *Technology Opportunities to Reduce U.S. Greenhouse Gas Emissions,* a.k.a. "The 11-Lab study."

This report outlines a broad range of technologies with the potential for reducing greenhouse gas (GHG) emissions and recommends their development as an essential component of a climate-change technology strategy. The focus of this report is reduction of U.S. GHG emissions through the development and application of new technologies. The report delivers two key messages: (1) advances in science and technology are necessary to reduce GHG emissions from the United States while sustaining economic growth and providing collateral benefits to the nation; and (2) success will require the pursuit of multiple technology pathways, providing choices and flexibility for reducing GHG emissions

The report describes technology development efforts that need to extend through the first third of the next century. The new technologies introduced at the end of the 30-year planning horizon of this report will have impacts that extend throughout the next century.

Driver 2: Deregulation

I believe the second major driver that is impacting the RD&D Program is deregulation. Deregulation of the electric and gas power industry in the U.S. is expected to have a significant impact on RD&D. In a highly competitive environment, it is difficult for profit-making energy companies to justify significant RD&D expenditures with pay-off times that are longer than a few years. Development of new, efficient, and environmentally friendly energy technologies is extremely costly and the lead time to move them from concept to commercial use is extremely long — typically 10 to 20 years. We have already seen the impact that deregulation is having on the budgets and research programs of the Electric Power Research Institute (EPRI) and the Gas Research Institute (GRI).

California's Assembly Bill 1890 (AB 1890), enacted in September 1996, deregulated the State's electricity industry. That landmark bill recognized the negative effect of deregulation on R&D and established a fund to encourage public interest research (e.g., for "green" energy technologies.) The annual fund is generated by a retail wire charge on electricity. Subsequent decisions allocated $61.8 million annually to the California Energy Commission (CEC) for public interest RD&D (non-transportation and distribution, or non-T&D). In addition, AB 1890 directed the collection of $540 million from investor-owned utility ratepayers over a period of 4 years (1998 to 2001) to support existing, new, and emerging renewable energy technologies.

Other States are closely watching California and may also establish energy RD&D funds. The net effect of this trend could be a "Balcanization" of energy RD&D into separate programs that fund research within each state to meets the perceived needs and special interests of that state. Pulling together support for a program to solve national problems that benefit all states will be a significant challenge in the next few years.

Driver 3: Air Quality Regulation (NO_X, PM2.5, SO_2, Hg)

The third driver is the lowering of permissible emission levels, affecting nitrogen oxides, particulates, sulfur dioxide, and mercury. On July 16, 1997, President Clinton approved the issuance of new ambient air quality standards (NAAQS) to provide new health protection by further controlling pollution from ozone and particulate matter. The initiative will establish regional limits on NO_X and particulates (PM2.5) that go into effect between 2007 and 2009. The standard for ground-level ozone will ratchet down from the current standard of 0.12 ppm to 0.08 ppm, while a secondary particulate standard dealing with particles less than 2.5 μm will be implemented in addition to the current one for particles less than 10 μm. Both of the new NAAQS directly impact NO_X emissions from power plants because NO_X is implicated in ground-level ozone formation and PM2.5 particles are formed in the atmosphere by secondary reactions of NO_X and SO_2.

EPA estimates that 74 million Americans will be living in PM2.5 non-attainment areas as a result of the new regulations. Utilities may be required to reduce NO_X emissions an additional 60 percent from Clean Air Title IV requirements.

Also, 37 eastern states will be required to develop implementation plans to lower NO_X emissions from point sources, primarily utilities. The projected limits on NO_X emissions from coal-fired power plants to meet the proposed ozone regulations is 0.15 lbs/MM Btu. Already, easternmost states are instituting actions against their western neighbors because transported NO_X will prevent meeting ozone attainment regulations.

Projected costs to the utility industry, as a result of the new NAAQS, are around $12 billion per year.

Mercury: for those of you who follow regulatory issues affecting coal-fired power plants, the situation is equally gloomy. EPA will most likely release the Mercury Report to Congress this December, after several years of review and debate. EPA has concluded that there is a plausible link between mercury emissions into the atmosphere from anthropogenic activities and mercury contamination of fish. In the revised version, utilities will be listed as the number one emitters of mercury because of recent regulations affecting municipal and medical waste incinerators. The findings of the Mercury Report will form the basis of a regulatory decision regarding mercury emissions from power plants that will be part of a second EPA report, the Utility Study, now scheduled for release in January 1998. The general consensus is that mercury emissions from power plants will be subject to regulation. **The costs of controlling mercury range widely, from $2 to 12 billion per year according to an EPRI estimate.**

Driver 4: Vulnerability to Oil Supply Disruption (FT Diesel)

The fourth driver that affects the R&D program is the vulnerability of the U.S. economy to oil supply disruption. As we all know, supply disruptions have a huge impact on the economy. That became apparent during the oil embargoes of the 1970s, the mid-1980s oil crisis, and from the impacts of the Gulf War early this decade.

Even with our strategic petroleum reserve and a military force that can fight two small wars at once, we are vulnerable: (1) our oil imports will increase to 61 percent of our total consumption in 2015; (2) by 2015, OPEC will supply over half our imports; and (3) by 2015, OPEC will also supply 72 percent of the world's oil.

Moreover, oil reserves are finite. Some experts feel that world oil production will peak in the period 2015 to 2020, and then will irreversibly decline. This includes experts from MITRETEK, World Resource Institute, Shell Oil, and British Petroleum. Other experts feel that, if demand exceeds supply, prices will go up. At higher prices, more oil will be produced. We currently leave 80 percent of the oil in the ground — so more is available, at a price.

From the DOE fossil-energy perspective, liquid fuels from natural gas and coal are a high priority R&D topic. The U.S. has lots of natural gas and coal. With new technology, liquid fuels from natural gas and ultimately coal can become an economic reality. These fuels, such as FT diesel, can burn cleanly in advanced engines and at extremely high efficiency.

Driver 5: Federal Budget Pressures

The fifth driver is collectively termed Federal Budget Pressures.

Reduced Spending: The requirement to balance the budget is producing tremendous pressure on Congress to reduce discretionary funding, like R&D programs. The impact on the fossil energy RD&D budget has been serious. In FY 1996, Congress set a glide path for the fossil energy budget that would cut it in half over a period of 5 years. Although the FY 1997 and FY 1998 budgets survived with less than the 10-percent-per- year reduction, the message is clear: ***no new starts***. In some programs, Congress required down-selections to reduce the number of program participants and out-year mortgages. Many of the R&D program elements are scheduled to conclude between FY 2001 and FY 2003. The Clean Coal Technology program is also coming to an end as the projects complete their demonstration phase.

Accountability: The Government Performance and Results Act, or GPRA, was passed by Congress in 1993. The Act demanded that all Government programs contribute to measurable, desirable outcomes. The outcomes must benefit the public — and be something that the private sector cannot or will not do on its own.

R&D programs are not exempt — they must produce measurable outcomes — for example, tons per year of pollutant reduced. These measures are used as part of the budget formulation process. Starting in the FY 1999 budget cycle, DOE's budget requests to Congress will be based on amount of public good achieved, for example, the potential for future emission reductions. This will likely impact the future direction of the program as well.

New R&D Approaches: Over the past few years, Congress and the Administration have had diametrically opposed views of R&D. Congress held that "basic research is good, and applied research is bad — it's corporate welfare." The Administration championed "technology partnerships with industry" as the cornerstone of economic development.

To solve this impasse, Congressional leaders are attempting to reach a consensus on a new R&D model — a model that would blur the border between basic and applied research. The emerging model is based on partnerships among government, universities, and industry. Partnerships leverage the Government and the private-sector's investment in R&D. Industry involvement ensures the relevance of the R&D. The model calls for consortia to: (1) focus on a defined problem, for example, to develop an 80 mpg car; and to (2) cut across an industry, for example, all gas turbine manufacturers. Industry produces a road map of technology needs and it may share ideas. This model suggests, but doesn't demand, that the research be pre-competitive. The new R&D model could become a requirement — we invite your comments on how we can make it work.

The ATS Program — Providing Solutions

Now let's turn to the ATS Program. How are these drivers affecting us and what successes are we having in the Program? There is no doubt that advanced turbine systems fueled by natural gas or a coal-derived synthesis gas will take on a significant role in providing heat and energy for power generation and cogeneration in the foreseeable future. The Energy Information Agency estimates that gas turbines will satisfy as much as 81 percent of new electric power demand in the United States over the next decade. Gas turbines will be the power generation technology of choice in the deregulated marketplace. Utility ATS will provide cost-effective, low-emission, reliable power for the competitive power industry.

Advanced gas turbines will play a key role in reducing concentrations of NO_X and greenhouse gases in the atmosphere. Because of their high efficiency, ATS will emit less NO_X and CO_2 than any other competing fossil-fuel technology, thus providing an alternative for meeting future electrical energy demands while minimizing their contribution to global warming.

The ATS program is a new R&D model — a working and successful example of the emerging model supported by Congress and the Administration. Many of the partnerships developed within the gas turbine industry under the ATS program could evolve into a broader, nationwide consortia of national laboratories, universities, government, and industry to solve future global economic and environmental energy issues.

Results Are in the Marketplace Now, Research is Relevant, and Major Technological Breakthroughs Have Been Achieved — The ATS Program is a Successful Model for National R&D Consortia.

Industry Partners (GE, Westinghouse, and ABB) — Some of the advanced features developed through the ATS Program are already being incorporated into turbine manufacturers' current products. Technologies such as thermal barrier coatings (TBCs), thermal-wave imaging, non-destructive evaluation, and advanced seals have contributed to improvements in current turbine products. Technology breakthroughs have been made in the validation of steam cooling, compressor performance, and casting of utility-scale single-crystal turbine components.

University Partners — Under the university Advanced Gas Turbine Systems Research (AGTSR) consortium, 40 research contracts at member universities are performing research that is relevant and valuable to the gas turbine industry. The AGTSR has organized seven workshops in various gas turbines technologies, such as combustion, heat transfer, materials, and sensors. Significant contributions have been made in unsteady measurements of fuel/air mixtures in combustors, turbomachinery design models, a unique chemical vapor deposition process for TBCs, and control strategies for instability problems in lean pre-mix combustors.

The AGTSR has now expanded to a nationwide network of 92 universities with 7 corporate members extending a presence to 37 states. The AGTSR has sponsored 41 research projects directed toward improving efficiency, cost, and reliability of land-based gas turbines. These research projects have fostered at least 105 partnerships between universities, industry, and government.

National Labs(Oak Ridge/FETC) — National labs have made significant contributions to the ATS program in the areas of combustion and materials. Novel methods to control low-emission combustion instability have been developed and successfully tested with an industrial gas turbine manufacturer. Tests are underway to evaluate the potential for high-performance humid-air combustion turbine cycles. Materials breakthroughs have been achieved in the reduction of alloy sulfur levels, production of large single crystal castings, and new turbine blade inspection methods.

The ATS Program established the objective for gas turbine systems to achieve greater than 60 percent system efficiency with superior environmental performance at a lower cost of electricity. Today, prototype ATS components are being manufactured and tested under turbine operating conditions. The ATS program is a major challenge on the threshold of reality: the marketplace is awaiting the commercialization of ATS products. Thus, completion of the ATS program and successful prototype testing of the ATS are critical to sustain U.S. gas turbine industry dominance in the global marketplace.

In closing, the U.S. needs to reconcile our economic and environmental imperatives. It is up to us in the scientific and technical community to weigh in on how best this might be done — or we will be told how it will be done.

Thank you.